COMPARATIVE DESCRIPTION OF COAL FEEDING SYSTEMS FOR FIXED BED PRESSURE GASIFICATION

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ABSTRACT

The trend in coal gasification can be characterized as increasing pressure, increasing throughput per gasification unit and, as far as possible, the use of run of mine coal.

With regard to these criteria coal feeding systems are discussed which are capable of feeding 20-100 T/H and the range of pressure is up to 100 bar. Most emphasis is placed on dry feeding systems, of which commercial proven and those being developed are dealt with.

The systems outlined are subdivided into continuous and intermittent and the influence of each system on lock gas losses and reactor design is shown.

Finally a cost estimate based on a Lurgi gasifier as example is presented which indicates the areas of preferred application and permits conclusions to be drawn regarding the economics of the various systems.

The presentation consists of two parts which will be delivered by Dr. Rainer Reimert, Lurgi Mineraloeltechnik GMBH, Frankfurt/Main, and Erwin Funk, Kamyr Inc. Glens Falls.

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by

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The subject of this paper is briefly "Coal Feeding Systems for Fixed Bed Pressure Gasification". The Lurgi lock hopper system which has been successfully applied for this duty for many decades is discussed first. Thereafter a pump is presented which can handle solids in dry condition and which has been developed to a pilot scale. The discussion over the dry feeding systems concludes with a comparison of the costs of investments.

The slurry systems are dealt with next and the necessary requirements for their use in connection with fixed bed gasification are outlined. At last Erwin Funk will present the Kamyr feeder system which has already proved its merits for pipeline feeding and which we hope can soon be tried out for fixed bed gasification.

1. Lurgi Lock Hopper System

Figure 1 shows a lock with closures which operates discontinuously. Coal travels from a bunker through the open top closure into the atmospheric lock, the bottom closure being closed. A vertically movable filling pipe prevents overfilling of the lock. When the lock is filled, the top closure is also closed and the lock pressurized with gas to

reactor pressure. External gas or cooled product gas is used for pressurizing. In the latter case a lock gas cooler is required in plants without complete condensation to avoid a pressure drop within the lock due to cooling and condensation of vapours, which besides could lead to undesired agglutination.

The contents of the lock is discharged through the opened bottom closure into an intermediate hopper which in the case of fixed bed gasification is arranged direct in the reactor above the coal distributor. Unloading is then in accordance with the coal consumption at the pertinent gasifier output and the level is indicated either by a level gauge or by temperature measurement. After complete unloading the bottom closure is closed and the lock vented via a valve.

The vent gas is collected in a gas holder and used, for instance, for firing. It can also be recompressed and fed to the product gas system. The gas holder or compressor are common for a plant consisting of several gasifiers.

Figure 2 presents the pressure-time chart of one lock cycle which was measured on a lock of roughly 5 m^3 volume in the Westfield Plant. 100% on the abscissa correspond to about 5 minutes. This time obviously depends on the coal flowing properties. 4-7 lock cycles per hour are operated in commercial plants. The diagram shows the 4 phases of one cycle: charge, pressurize, feed, vent. The hold point during venting at about 275 psig denotes the pressure test for checking the leak-proofness of the bottom closure.

The closures have hard-faced metallic seating surfaces. For safety reasons, the closures are so installed that the working pressure keeps the closure closed which produces an additional sealing effect. For example, the working pressure of the new Mark IV gasifier produces a pressing force of about 50 tons.

Figure 3 illustrates a lock connected to the gasifier. The coal intermediate hopper mentioned already earlier and serving as storage compartment is arranged between bottom closure and coal distributor. It is also evident that by making a few modifications the same system is used as ash lock.

Figure 4 shows a view of the coal locks in the Dorsten Plant. While in this old plant the lock operations were controlled manually by the "Captain's Wheel" in the foreground, modern coal locks operate fully automatically.

The volume of the old Dorsten coal lock was about 5 m^3 and the design pressure 27 bar. The coal lock for the improved Mark IV Gasifier at SASOL now has a volume of about 15 m^3 which permits a coal feeding rate of about 70 t/h at a plant pressure of 30 bar. The maximum working pressure applied so far, with the same design principle, was 80 bar in a pilot plant for lignite hydrogasification in the fluid bed at Union Kraftstoff Wesseling which has operated trouble-free already for some months.

The losses of compressed gas during lock venting increase with increasing reaction pressure. These losses can be reduced by about 30–40% by using parallel connected double locks with reciprocal pressurizing and venting. The incorporation of additional parallel operated locks would reduce the losses only by a few more percent. The reduction of the vent gas losses is realized at the expense of an increased investment for vessels, valves and instruments.

Another but very important advantage of the double lock is its high coal throughput. In view of the parallel connection it is possible to operate the gasifier at 70% of its previous capacity in the event one of the locks fails.

The principle of the double lock with reciprocal pressurizing and venting will be applied in a pilot plant for two-stage fixed bed gasification at maximum 100 bar which is scheduled to go on stream at Dorsten in 1979. This arrangement is shown on the diagram in Figure 5.

The cycle times for the lock system operating at 100 bar are illustrated in Figure 6 for various schemes. The reciprocal pressurizing and venting increase the cycle time of the double lock again by about 30% versus a double lock operated independently. A series connected double lock with reciprocal pressurizing and venting is shown as the last case where, however, only a little increase in throughput can be realized compared to a single lock. The time for feeding the gasifier is assumed to be 100 s in each case.

2. Piston-Type Pump System

The LURGI lock hopper system has the advantages

- that it can handle all sizes and grades of coal in dry condition, and practically without size degradation,
- that it can overcome high pressures in one stage, and
- that the system has proved successful during many years of commercial operation,

but shortcomings are that the lock operates discontinuously and that vent gas occurs.

The variations in the coal supply caused by discontinuous feeding have no negative effects on the fixed bed reactor in view of its large coal volume. With a view to reducing the increased output of vent gas particularly at high reactor pressures another principle was invented about 30 years ago. This system is being realized at present.

Figure 7 presents the patent drawing of a system in which the vent gases are reduced to a minimum. It operates similar to the Lurgi lock except that the top closure has to be regarded as displacer. Cylinder 'c' is filled from coal bunker 'a' via dosing facility 'b' with piston 'd' in its upper end position and bottom closure 'e' closed. This closure can be arranged similar to that of the Lurgi lock. The cylinder is filled only so far that piston 'd' can still be moved downwards beyond the feed port without resistance. Hereby the coal is not pressed. The piston seals the cylinder compartment holding the coal, which is then pressurized with product gas through line 'h'. After pressure equalization bottom closure 'e' can be opened and the coal drops into reactor 'f'. Piston 'd' follows up

to the lower cylinder end thereby removing coal remnants from the cylinder. After closing the bottom closure only a very small volume, compared to the volume fed, remains which contains gas at reactor pressure. After withdrawal of the piston this gas is available at sub-atmospheric pressure and causes only negligible emission.

A pump operating according to the principle outlined is currently under fabrication for a feed rate of some 20 t/h. The system still has to be tried out for feeding coal into pressure vessels to clarify in particular wear and power consumption. The bottom closure is designed as rotating cylinder with horizontal borehole. The piston front face is adapted to the configuration of the cylinder to keep the empty volume of the lock low when the piston is in its lower end position.

To avoid that the piston always has to be moved over the feed slot, an improvement of the system provides for feeding the coal direct through the piston into the cylinder.

Apart from the drastic reduction of the vent gas rate a further advantage of the system is the quasi-continuous conveying which enables a reduction of the hopper volume in the gasifier resulting in a lower gasifier height.

3. Comparison of Costs

A comparative cost estimate shows that a piston type pump also has economic advantages at least when low throughputs are involved. The investment costs of some Lurgi lock systems and of the piston type pump are plotted in Figure 8 versus the coal throughput. The Sasol lock with a throughput of 50 tons/hr was taken as reference point = 100%. The curves have been established by extrapolation based on the designed throughput. Those costs, which are influenced by the throughput, have been calculated using the power 0.7.

Remarkable are the high costs estimated for the double lock system for the Lurgi pressure gasifier Type Ruhr 100. This is due to the higher investment for material for the lock vessels and for piping and instrumentation required for reciprocal pressurizing and venting. Also the higher plant pressure adds up to the investment costs. Furthermore, these costs have to be viewed under the aspect of partial vent gas recovery for which otherwise an additional compressor station would have to be provided.

The curve for the piston type pump is at the lower end. It should be considered that commercial experience with this system is not yet available so that the actual costs are likely to be higher compared to the original estimate. The resistance of the material selected to the attack by erosion will play a major rôle.

The extrapolation of the costs considers that the capacity of these pumps will presumably be limited so that se eral pumps would have to be arranged in parallel. The cost advantage of the piston type pump is therefore mainly in the range of low coal throughputs.

4. Brief Summary of Dry Feeding Systems

Before discussing the slurry systems a brief summary of the features of the dry feeding systems should be given.

- The Lurgi lock has proved its merits on a commercial scale for pressures up to 80 bar and throughputs of 70 tons/hr. It can handle all coal grades and sizes.
- The quantity of vent gas which increases with increasing pressure can be reduced by the provision of double locks which results in higher investment costs but also in savings in energy. The vent gas can be recovered completely by recompression.
- The provision of a piston type pump for handling dry solids allows quasi-continuous opera..on and reduces the quantity of vent gas drastically. Such pump can have price advantages when low throughputs are involved.

5. Slurry Systems

Apart from the unavoidable vent gas losses, the dry feeding systems c te additional losses due to leakages and emissions during filling of the locks. These gases which contain mainly

CO and H_2S as harmful components can be largely disposed of by exhausting and subsequent incineration. The permissible CO and H_2S emission limits could nevertheless be reached when severe environmental pollution control requirements exist.

For this reason and for the continuous feeding in the event of very high throughputs per unit slurry systems can be a valuable alternative, provided of course that the gasification process remains largely unaffected. Counter current flow of coal and gasification agent are typical for fixed bed gasification. Therefore, liquids introduced with the coal do not take part in the reaction unless very high boiling hydrocarbons are involved. They are evaporated in the reactor top section which reduces the possibility of waste heat recovery from the raw gas. A rather complete separation of the transport fluid from the coal is therefore desirable. The separated liquid should be recirculated as it contains coal fines and dissolved gases. The moist coal entering the gasifier top section must have adequate flowing properties.

Fixed bed gasification of bituminous coal of the preferred sizes of 3 - 50 mm yields a residual liquid content in the coal of less than 15% after separation so that water can be used as transport fluid. The residual water content of other coal grades would have to be determined on a case-to-case basis.

Erwin Funk will now present the Kamyr slurry feeding system and its many advantages versus conventional slurry systems.

Finally I would thank my colleagues not named here who helped in preparing this paper.

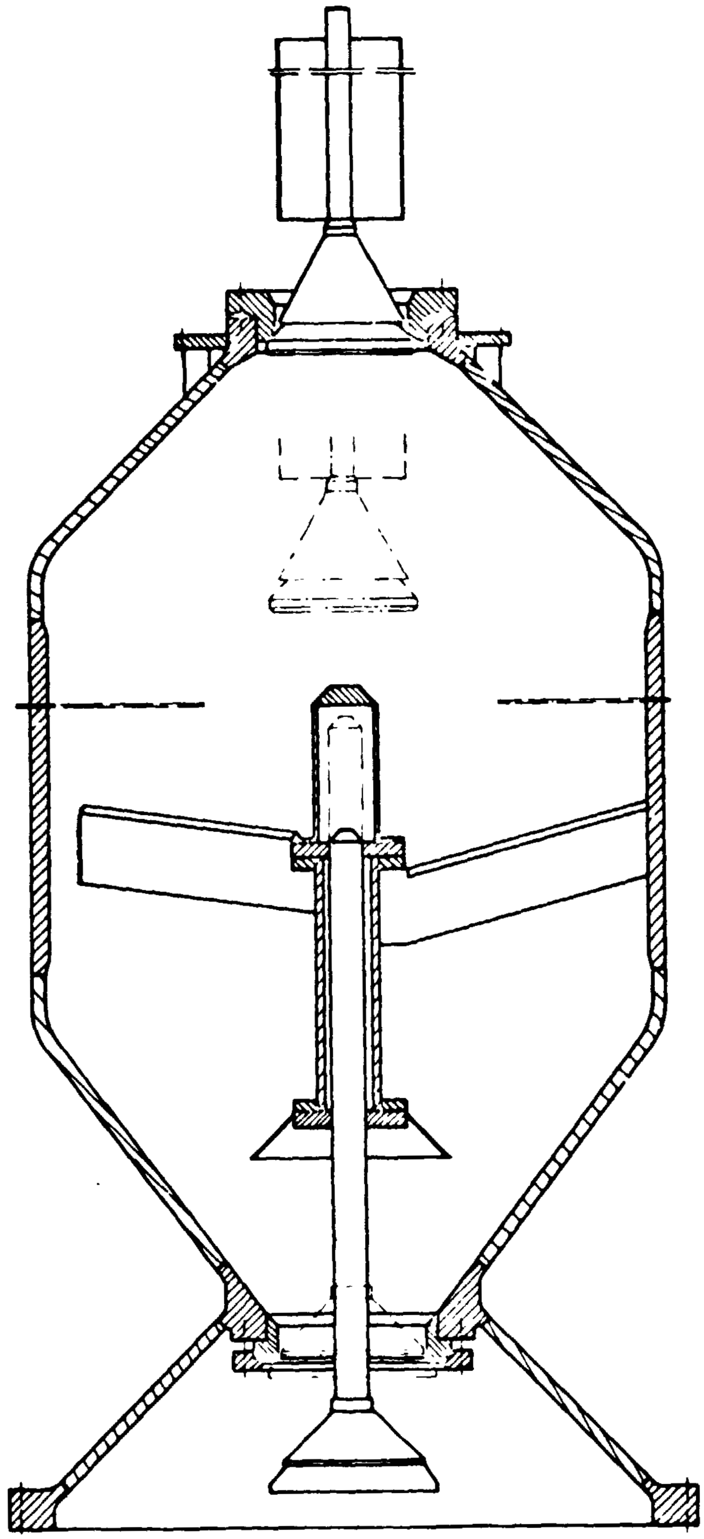


FIG. 1 LURGI COAL LOCK

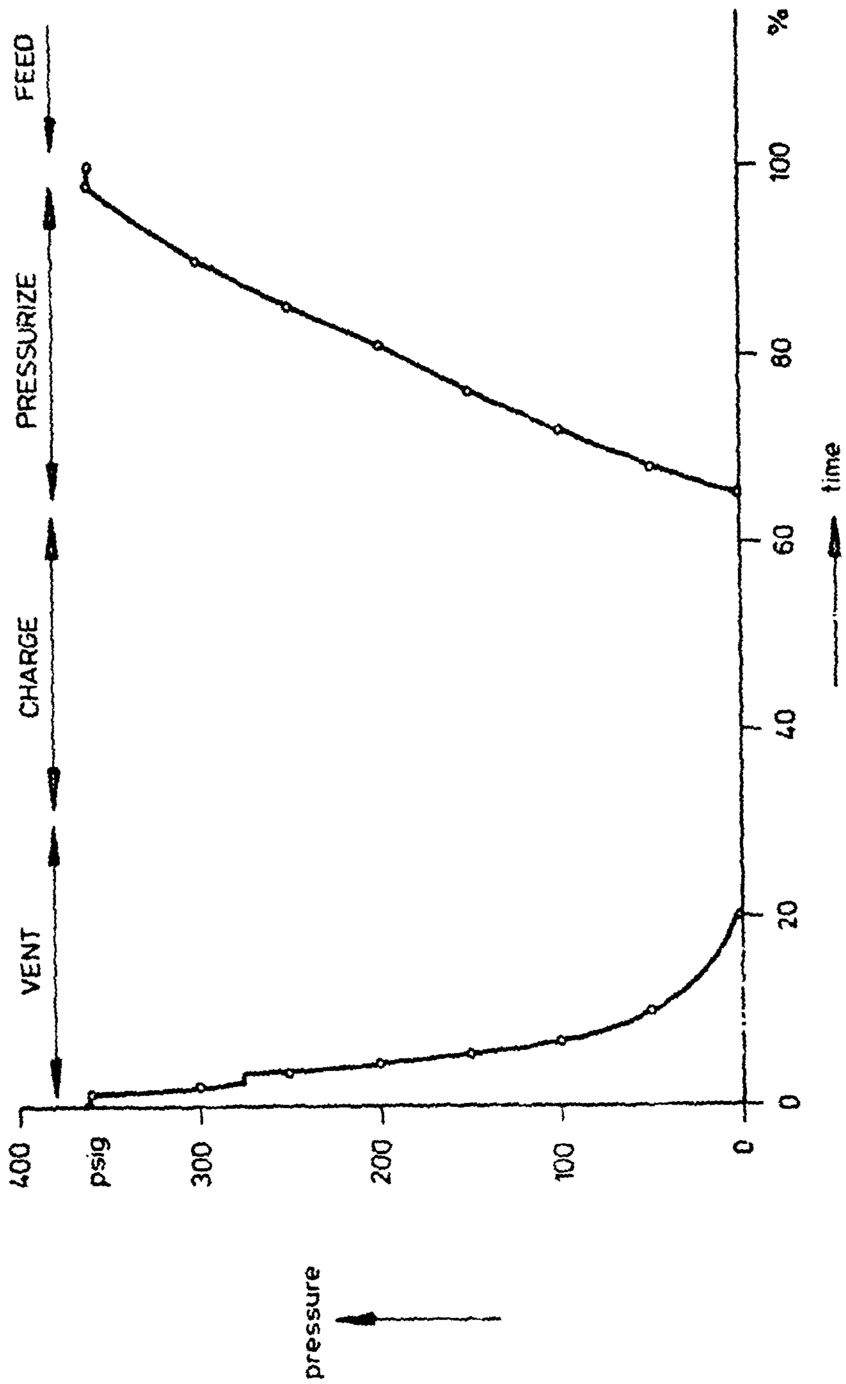


FIG. 2 COAL LOCK CYCLUS

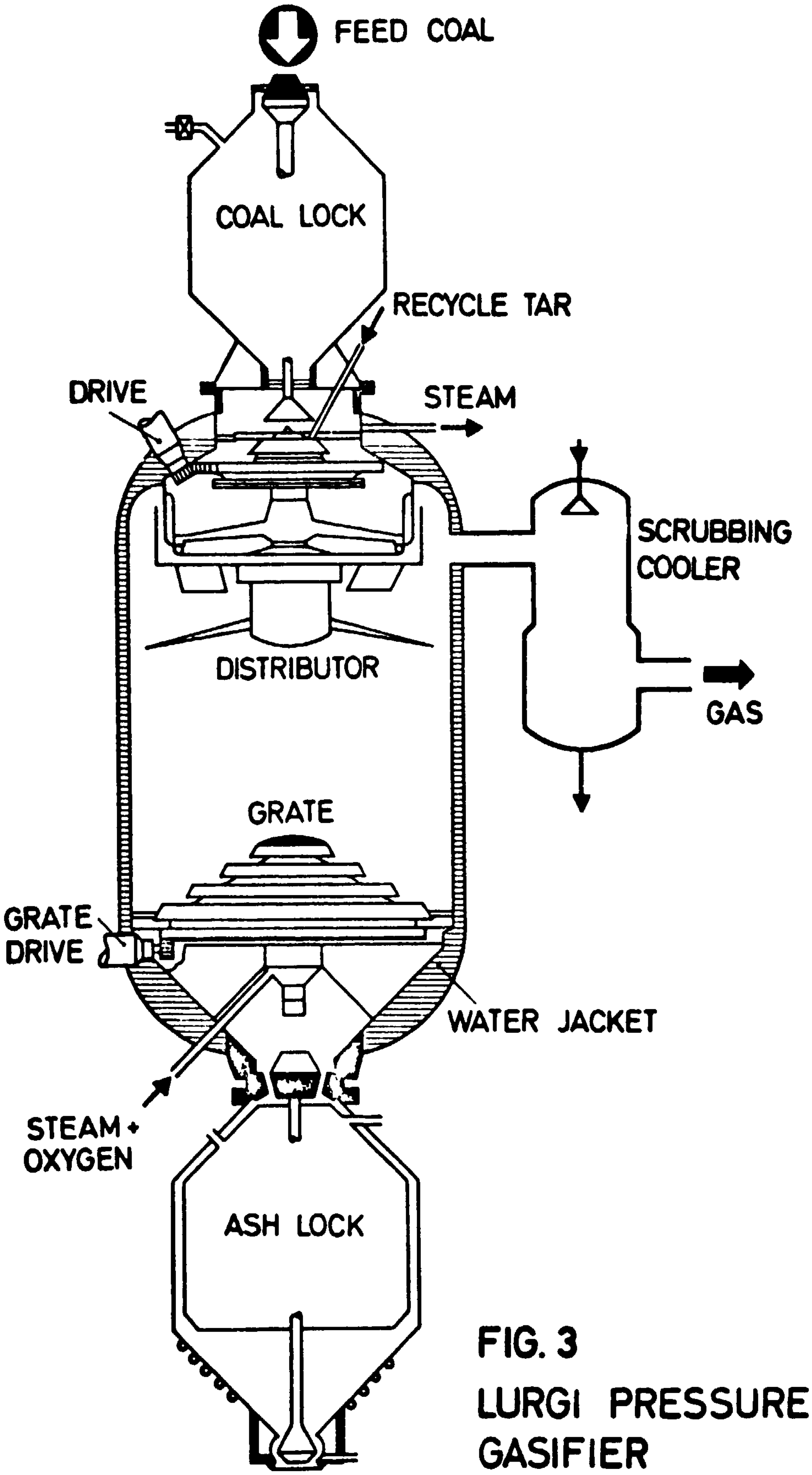


FIG. 3
LURGI PRESSURE GASIFIER

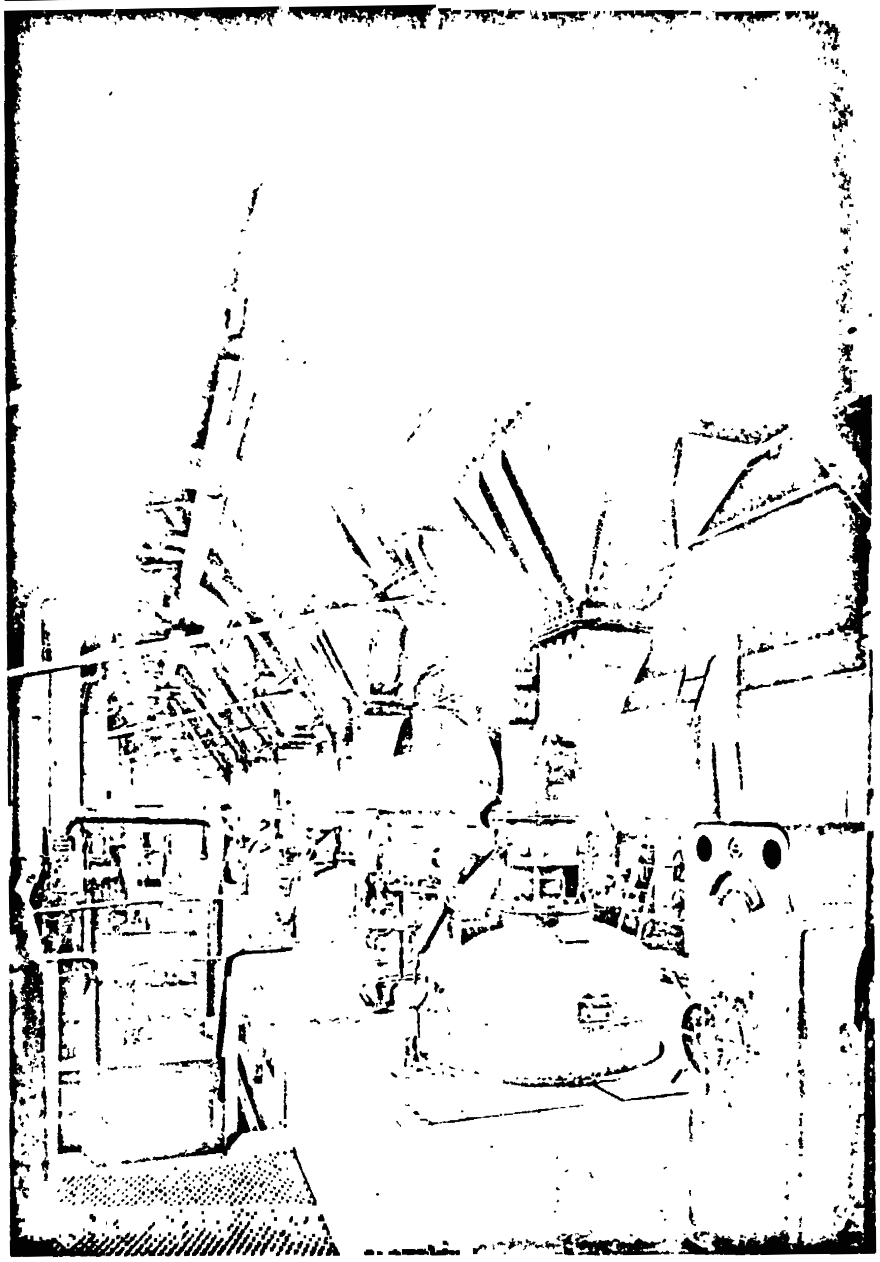


FIGURE 4 COAL LOCKS AT DORSTEN

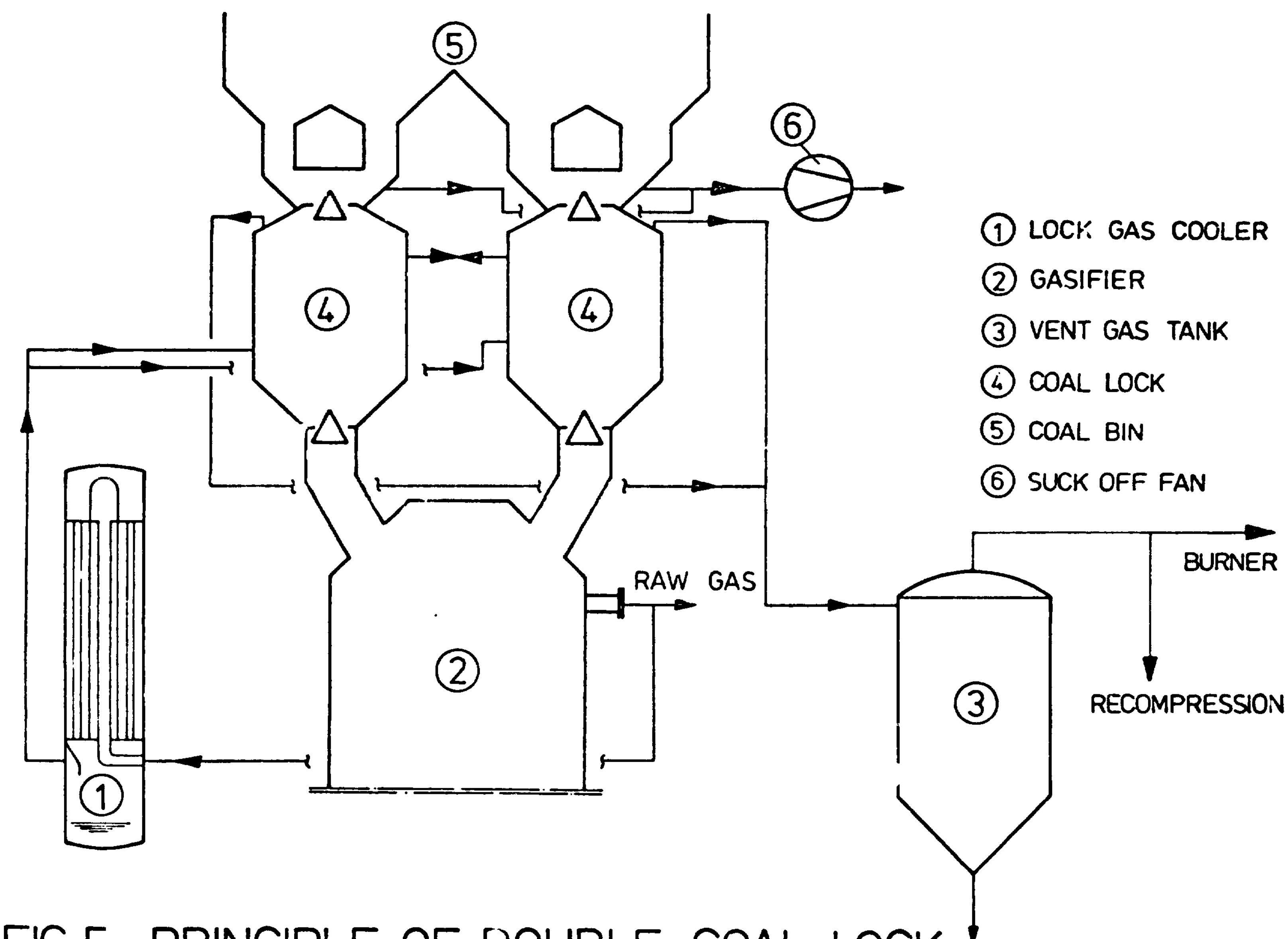


FIG.5 PRINCIPLE OF DOUBLE COAL LOCK

Coal Lock Arrangement			Period of Lock Cyclus: Seconds	Period of Lock Cyclus: %
SINGLE LOCK			594	100
DOUBLE LOCK	PARALLEL	WITHOUT *	347	58
		WITH *	450	76
	IN SERIES	WITH *	550	93

* RECIPROC/ LY PRESSURIZING AND VENTING

FIG.6 COMPARISON OF CYCLUS PERIODS

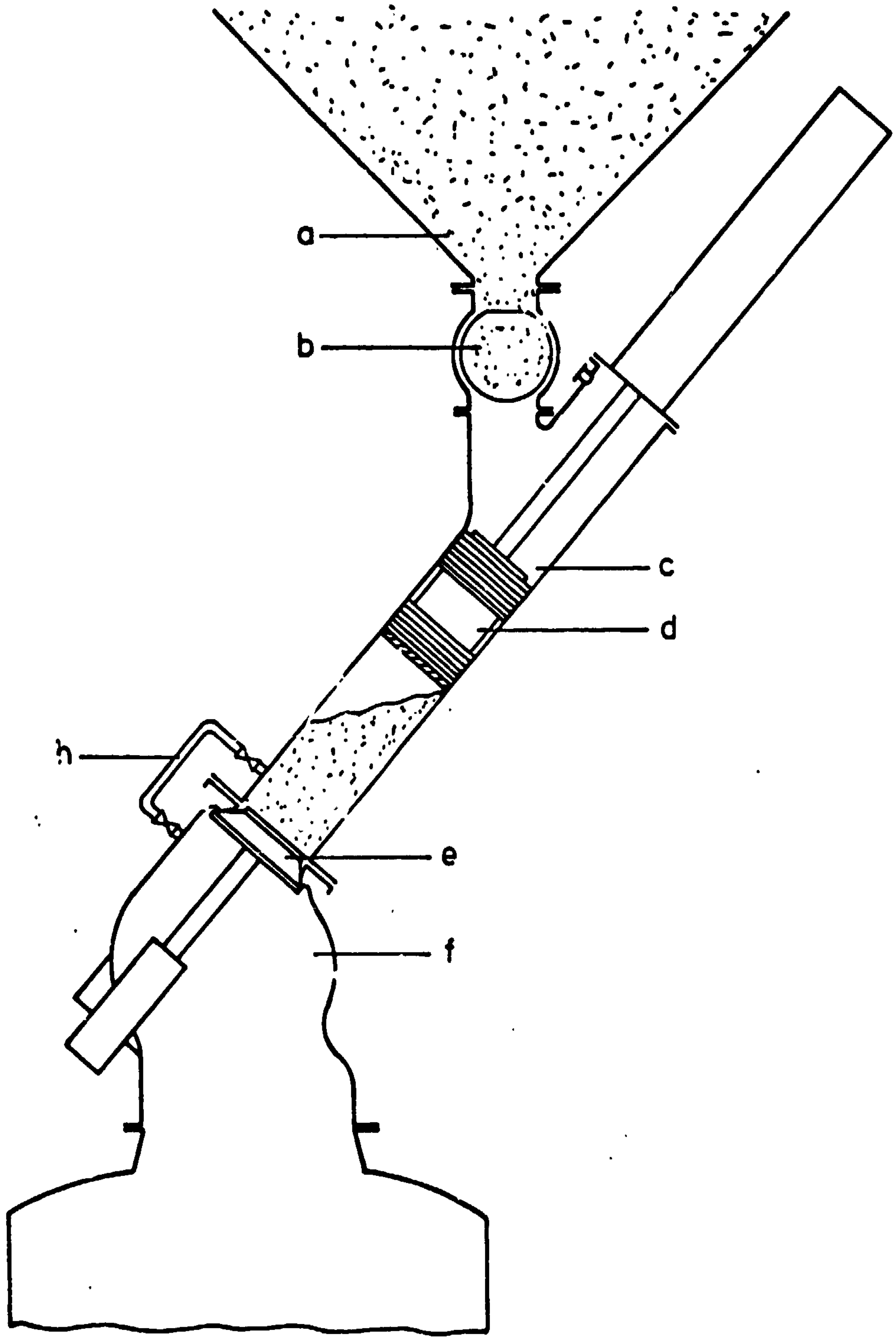
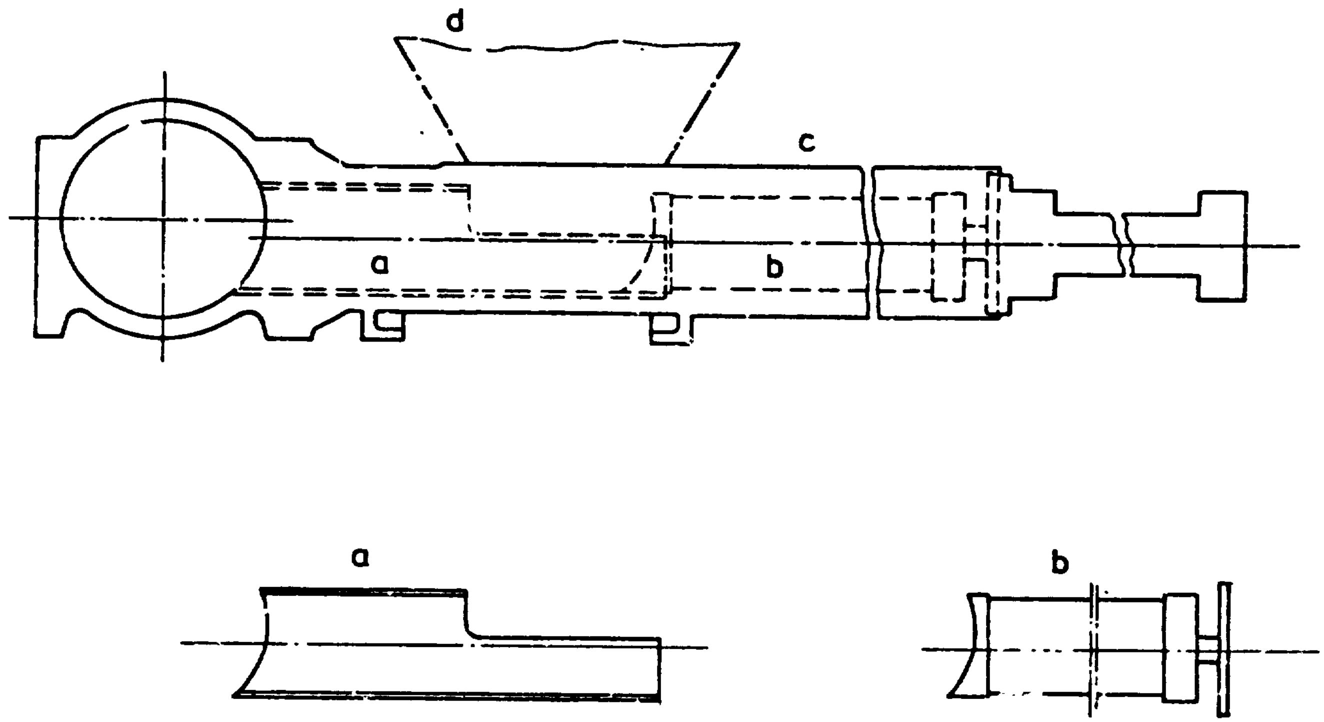


FIG. 7

SCHLEPPER SYSTEM FOR REDUCED VENT GAS



a LINER
b PISTON
c PUMP HOUSING
d FEEDING HOPPER

FIG.8 PISTON TYPE PUMP FOR DRY SOLIDS

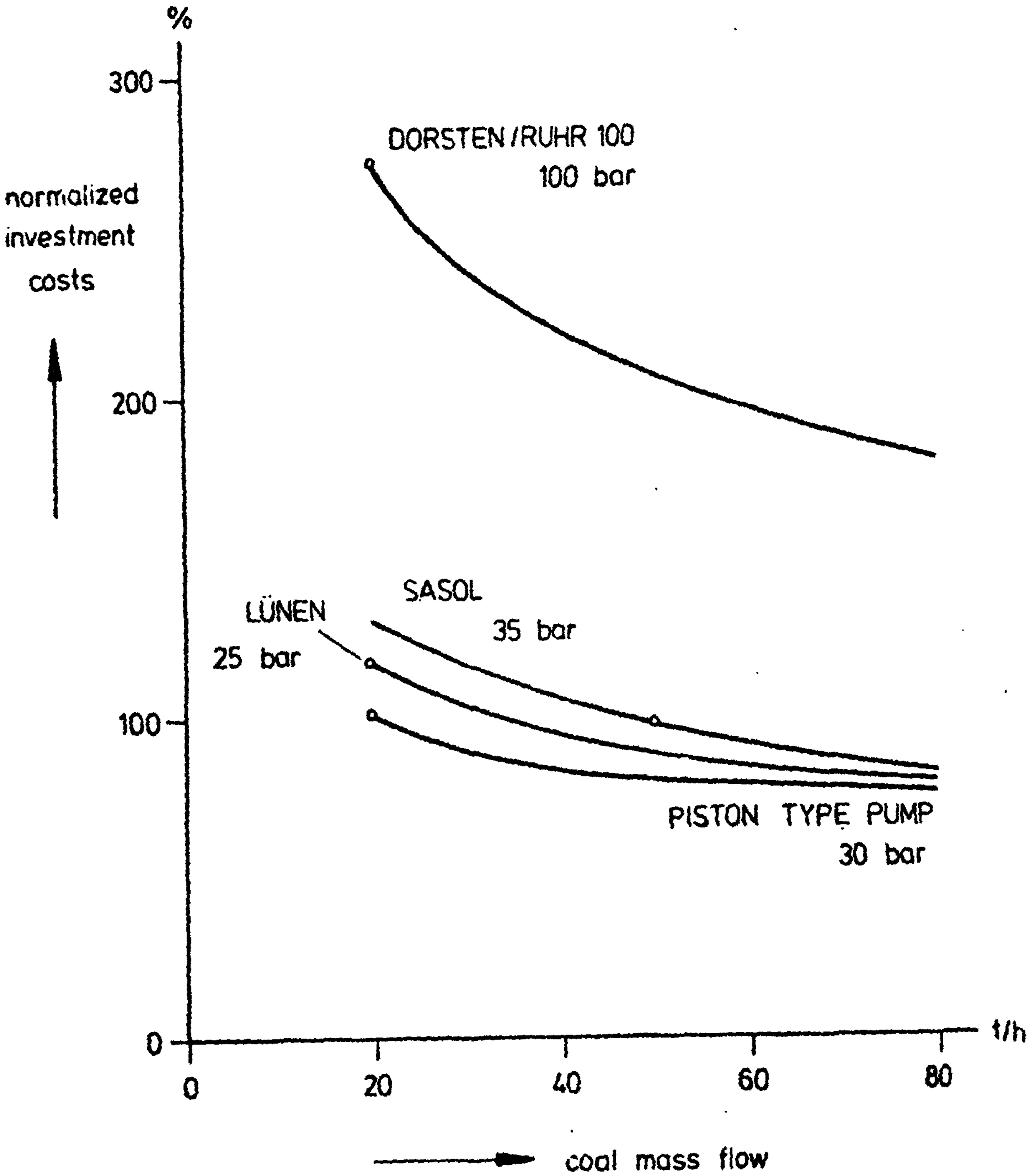


FIG. 9 COMPARISON OF INVESTMENT COSTS OF DIFFERENT FEEDER SYSTEMS

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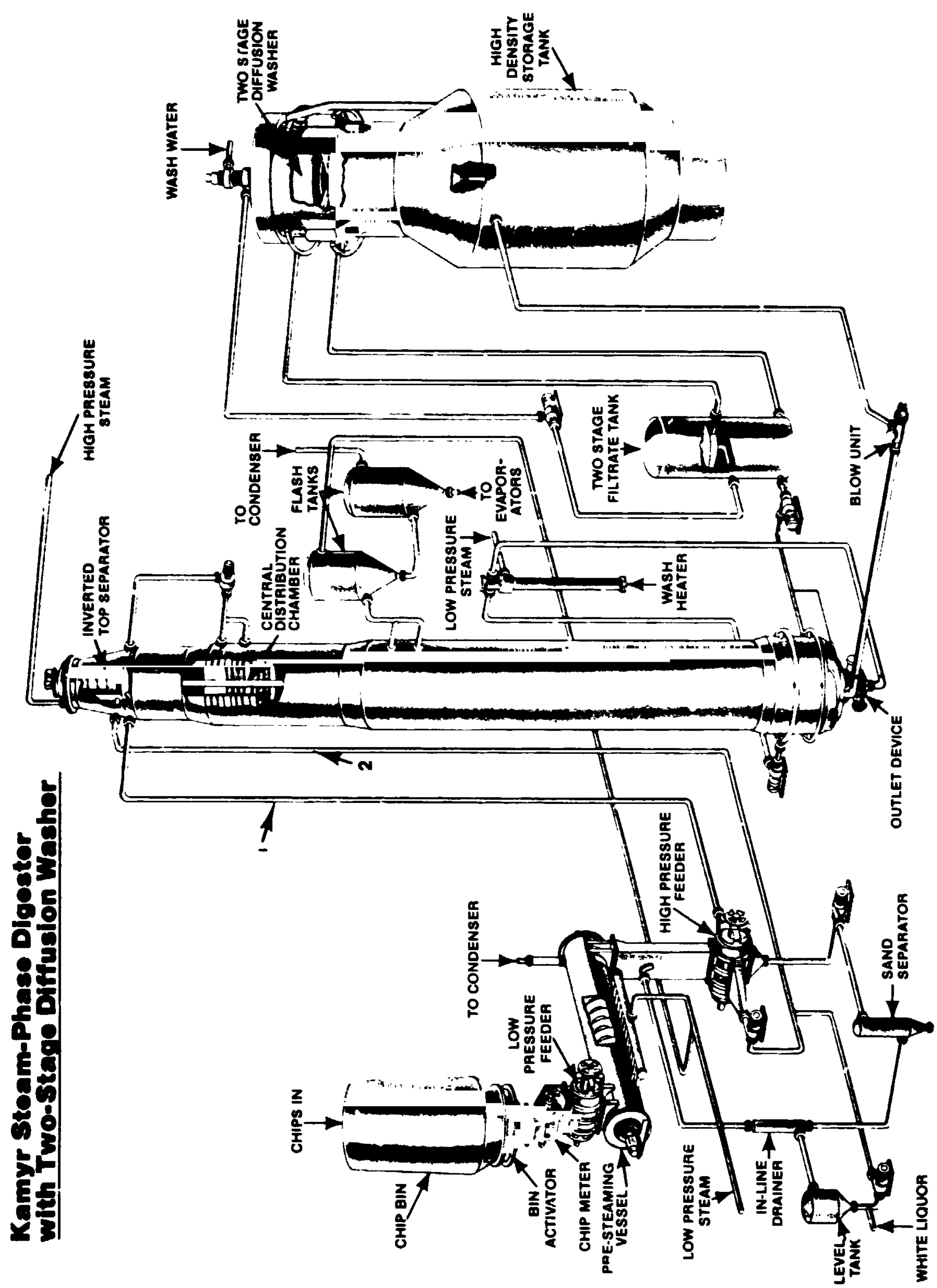

FIGURE 10

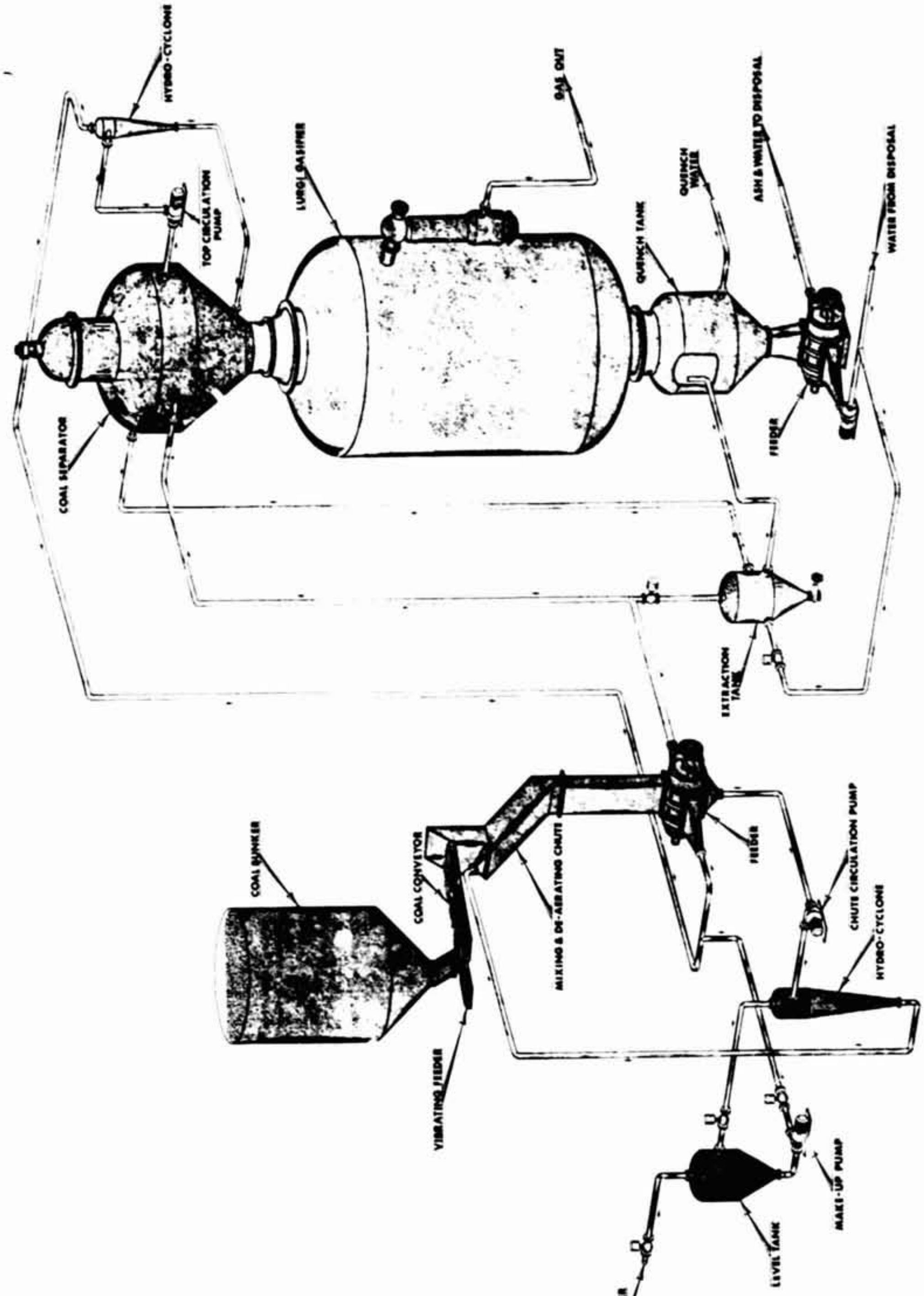
HYDRO-CYCLONE
TOP CIRCULATION PUMP
LURGI GASIFIER
GAS OUT
QUENCH WATER
ASH & WATER TO DISPOSAL
WATER FROM DISPOSAL
QUENCH TANK
COAL SEPARATOR
FEEDER
EXTRACTION TANK
COAL BUNKER
COAL CONVEYOR
MIXING & DE-AERATING CHUTE
FEEDER
CHUTE CIRCULATION PUMP
HYDRO-CYCLONE
VIBRATING FEEDER
MAKE-UP PUMP
LEVEL TANK
MILL WATER

FIGURE 11

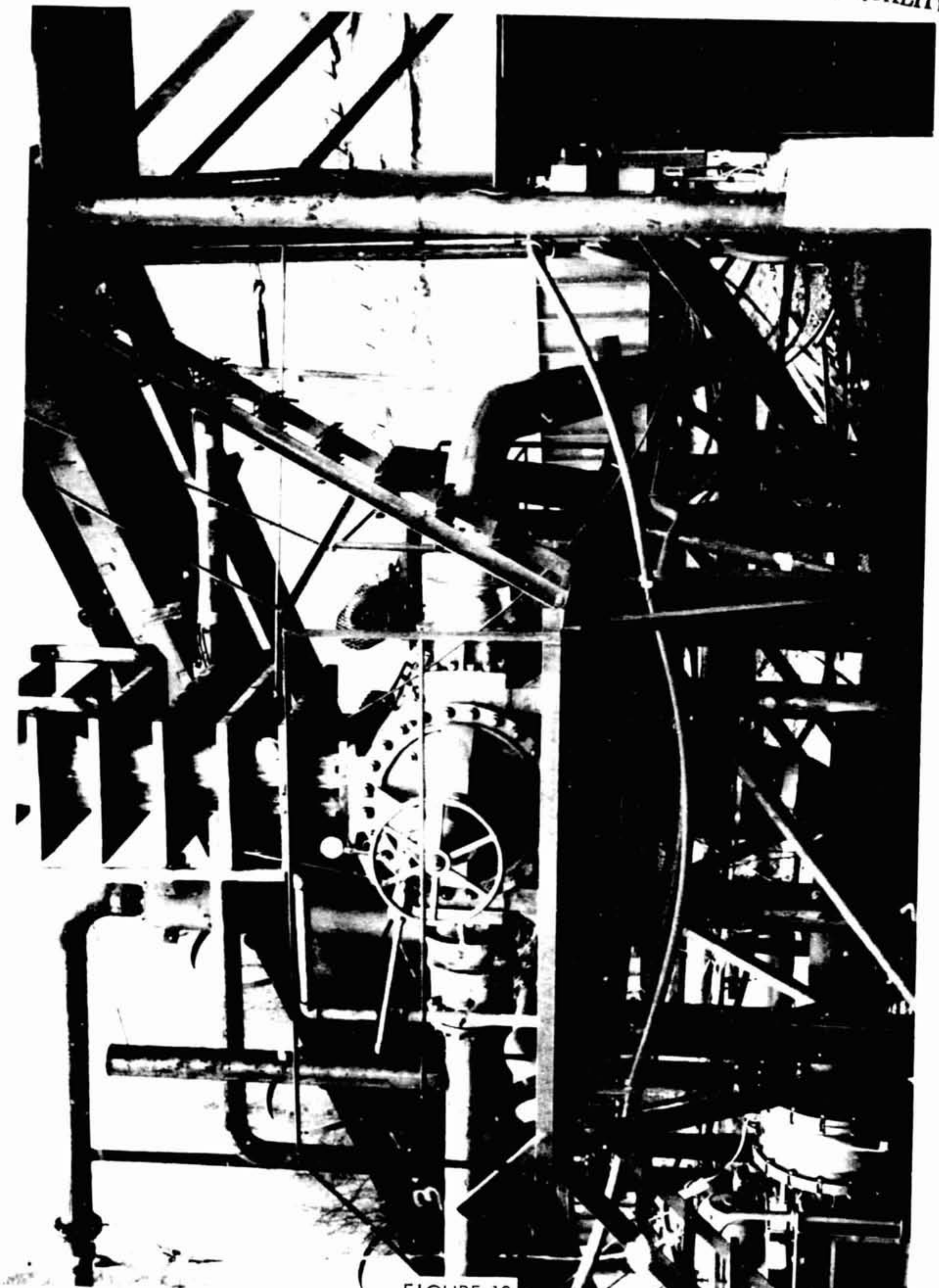

FIGURE 12

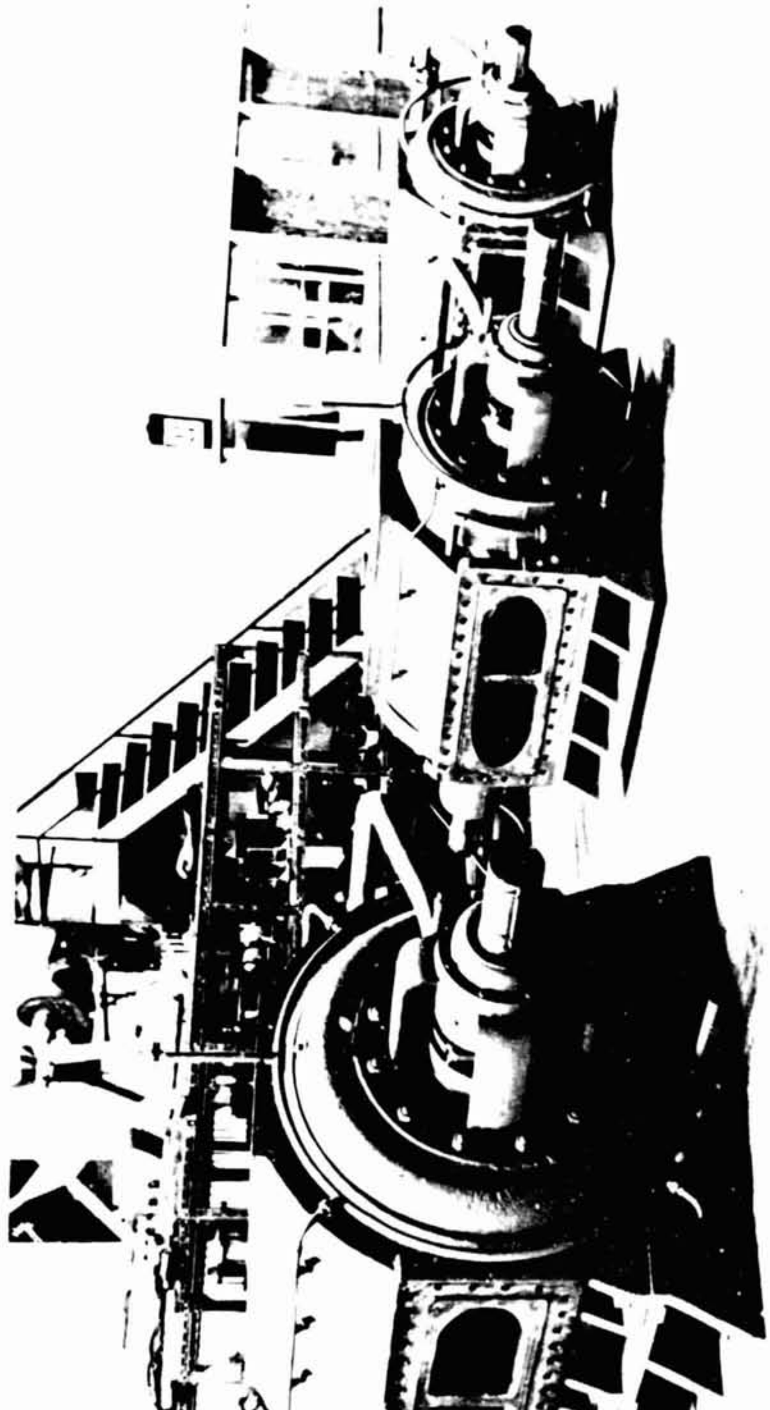

FIGURE 13

CONTINUOUS LUMP COAL SLURRY FEEDING

Slurry feeding of coal to gasifiers is most often thought of in terms of fine particles with high solids to liquid concentrations to minimize thermal penalties inherent with vaporization and condensation recovery of the liquid. A method is available to feed lump coal to gasifiers where the majority of the transport liquid is easily drained.

Lurgi and Kamyr have been working on adapting a proven method of feeding wood chips to a method for feeding lump coal. The wood chip feeding system years ago caused a revolutionary conversion of pulp making from a batch method to a continuous method. Worldwide, more than 250 major pulp mills are utilizing this continuous feeding method to feed over 40 Million tons of wood chips annually to pressure digesters.

The wood chip feeding system is illustrated in Figure 10 which is a reprint from Kamyr's Digester Sales Brochure. The object is to feed wood chips without passing the chips thru pumping devices. Additional objectives are to feed the chips without gas back flow and without pressure letdown of the liquid transporting circuit. The basic concept involves establishing a closed loop high pressure liquid stream. Chips are injected into this stream by the high pressure feeder and transported through pipe (1) to the top of the digester where the chips are mechanically separated from the transport liquid (NaOH solution). The liquid recirculates thru pipe (2) to continue the feeding.

The feeding system for lump coal is very similar and is shown in Figure 11 for a Lurgi moving bed lump coal gasifier. The separator is a redesigned version of those available for chip separation.

Kamyr and Lurgi began a cooperative evaluation of this feeding system in June 1974. The first step was a technical evaluation to determine feasibility. Next the key element, the high pressure feeder, had to be proven capable of transmitting coal. In November of 1974, Kamyr began design work for a pilot facility to test the operational capabilities of the high pressure feeder with a two-fold purpose of proval for gasification and for deep mine coal lifting or short distance pipelining. A photo of this pilot installation is displayed in Figure 12. The pilot installation was located at an Appalachian coal preparation plant where metallurgical coal is cleaned. Raw 4" x 0 coal was transmitted in a 10 inch pipe from a storage silo to the top of the preparation plant using a small Kamyr high pressure feeder. The coal was transported 450 feet horizontally and then 115 feet vertically. Raw coal rates were varied between 100 and 215 tons per hour and at velocities between 4 and 14 feet per second. Data was collected on pressure drop and size degradation. The raw coal contained approximately 35% refuse which was in the form of clay and hard shale stone. Some stones with long dimensions as great as 7 inches were transported.

The success of the feeder testing program meant that one more test phase was required; a separator design was to be established. The separator needed to be designed in such a fashion to prevent liquid discharge into the gasifier under failure conditions. An engineering and laboratory evaluation began in the Fall of 1975 and continued into the Spring of 1976. Two test models were fabricated and operated on coal. The testing included evaluation of surface moisture carryover to the gasifier. The surface moisture ranged from 13% with 1/4" x 0 particles to 3.2% with very coarse particles. The separator involves mechanically lifting the settled coal particles from the transport liquid. Water has been used in all tests; however, the transport liquid could be an oil or waste liquor.

The feeding system is totally automatic. Once liquid flows are established, the feed rate is governed by a gasifier demand signal to the bunker vibrating feeder shown in Figure 11. The high pressure feeder does not control the rate; it merely performs the transfer from low to high pressure. The high pressure feeder is not a star wheel. It is a pressure balanced rotary type of transfer valve. It consists of one moving part, the tapered rotor, with a plurality of diametrically penetrating holes that allow a continuous downward vertical flow through the feeder while at the same time allowing an independent high pressure horizontal flow thru the feeder. Coal is introduced into the downward flowing stream, stopped in the rotor by

screens in the lower port, and subsequently transferred by the turning rotor into the high pressure stream. The pressure balance of the high pressure feeder is a very important feature. This pressure balance can be visualized in Figure 11. The hydraulic pressures at the upper connection and lower connection are nearly equal except for a couple of feet of static head between the two connections. The hydraulic pressures at each horizontal side connection are equal. The opposing pressures all around the feeder are equal; therefore, the rotor is free turning within the housing requiring very small turning power. The absence of high hydraulic side loads on the rotor allow operation at high pressures. The pilot facility feeder operated with a 10 horsepower motor. A high pressure gasifier would require this same power for the feeder.

Three sizes of feeders are shown in the photograph of Figure 13. The far right feeder of the photo is the size used at the pilot facility. The largest high pressure feeder which is not shown has the capability of transferring coal at the rate of 500 tons/hr. Operating pressure designs for pulp mills are 350 psig. Designs have been finalized for 450 psig and designs for 1000 and 1500 psig are in progress.

The lump coal feeding system offers the following advantages:

1. The system is automatic and continuous.
2. No gas compressions are involved.

3. A liquid seal is created between the gasifier and the feeding system eliminating gas leakage from the gasifier.

4. Very large coal rates are readily available, thus allowing for bigger gasifiers.

5. No coal storage areas are required in the gas plant. The feeders may be located at a separate coal bunkering area.

6. Since the high pressure feeder is pressure balanced, large pressures can be achieved which is not possible with conventional rotary feeders where side loads are inherent.

The system now remains to be commercially demonstrated on a coal gasifier.